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**REMOTE COMMUNICATION DEVICES, RADIO
FREQUENCY IDENTIFICATION DEVICES,
WIRELESS COMMUNICATION SYSTEMS,
WIRELESS COMMUNICATION METHODS, RADIO
FREQUENCY IDENTIFICATION DEVICE
COMMUNICATION METHODS, AND METHODS
OF FORMING A REMOTE COMMUNICATION
DEVICE**

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1 REMOTE COMMUNICATION DEVICES, RADIO FREQUENCY
2 IDENTIFICATION DEVICES, WIRELESS COMMUNICATION
3 SYSTEMS, WIRELESS COMMUNICATION METHODS, RADIO
4 FREQUENCY IDENTIFICATION DEVICE COMMUNICATION
5 METHODS, AND METHODS OF FORMING A REMOTE
6 COMMUNICATION DEVICE

7 TECHNICAL FIELD

8 The present invention relates to remote communication devices,
9 radio frequency identification devices, wireless communication systems,
10 wireless communication methods, radio frequency identification device
11 communication methods, and methods of forming a remote
12 communication device.

13 BACKGROUND OF THE INVENTION

14 Electronic identification systems typically comprise two devices
15 which are configured to communicate with one another. Preferred
16 configurations of the electronic identification systems are operable to
17 provide such communications via a wireless medium.

18 One such configuration is described in U.S. Patent Application
19 Serial Number 08/705,043, filed August 29, 1996, assigned to the
20 assignee of the present application, and incorporated herein by
21 reference. This application discloses the use of a radio frequency (RF)
22 communication system including communication devices. The disclosed
23 communication devices include an interrogator and a remote transponder,
24 such as a tag or card.

1 Such communication systems can be used in various applications
2 such as identification applications. The interrogator is configured to
3 output a polling or interrogation signal which may comprise a radio
4 frequency signal including a predefined code. The remote transponders
5 of such a communication system are operable to transmit an
6 identification signal responsive to receiving an appropriate polling or
- interrogation signal.

8 More specifically, the appropriate transponders are configured to
9 recognize the predefined code. The transponders receiving the code can
10 subsequently output a particular identification signal which is associated
11 with the transmitting transponder. Following transmission of the polling
12 signal, the interrogator is configured to receive the identification signals
13 enabling detection of the presence of corresponding transponders.

14 Such communication systems are useable in identification
15 applications such as inventory or other object monitoring. For example,
16 a remote identification device is initially attached to an object of
17 interest. Responsive to receiving the appropriate polling signal, the
18 identification device is equipped to output an identification signal.
19 Generating the identification signal identifies the presence or location
20 of the identification device and the article or object attached thereto.

21 Some conventional electronic identification systems utilize
22 backscatter communication techniques. More specifically, the interrogator
23 outputs a polling signal followed by a continuous wave (CW) signal.
24 The remote communication devices are configured to modulate the

1 continuous wave signal in backscatter communication configurations. This
2 modulation typically includes selective reflection of the continuous wave
3 signal. The reflected continuous wave signal includes the reply message
4 from the remote devices which is demodulated by the interrogator.

5 6 SUMMARY OF THE INVENTION

7 The present invention relates to remote communication devices,
8 radio frequency identification devices, wireless communication systems,
9 wireless communication methods, radio frequency identification device
10 communication methods, and methods of forming a remote
11 communication device.

12 According to one aspect of the invention, a wireless
13 communication system is provided. The wireless communication system
14 comprises an interrogator and one or more remote communication
15 devices individually configured to communicate with the interrogator in
16 at least one embodiment. Exemplary remote communication devices
17 include remote intelligent communication devices or radio frequency
18 identification devices (RFID).

19 One configuration of the remote communication device includes
20 communication circuitry and at least one antenna configured to
21 communicate at a plurality of frequencies. The antenna is substantially
22 tuned to plural frequencies to implement communications. The remote
23 communication device includes a transmit antenna and receive antenna
24 in one embodiment. An exemplary transmit antenna comprises a dipole

1 antenna and an exemplary receive antenna comprises a loop antenna.
2 The remote communication device is configured for backscatter
3 communications in at least one arrangement.

4 The invention additionally provides methods and additional
5 structural aspects as described below.

6 7 BRIEF DESCRIPTION OF THE DRAWINGS

8 Preferred embodiments of the invention are described below with
9 reference to the following accompanying drawings.

10 Fig. 1 is a functional block diagram of an exemplary
11 communication system.

12 Fig. 2 is a front view of a wireless remote communication device
13 according to one embodiment of the invention.

14 Fig. 3 is a front view of an employee badge according to another
15 embodiment of the invention.

16 Fig. 4 is an illustrative representation of one substrate surface of
17 a remote communication device.

18 Fig. 5 is an illustrative representation of exemplary dimensions of
19 a transmit antenna of the remote communication device.

20 Fig. 6 is an illustrative representation of additional exemplary
21 dimensions of the transmit antenna.

22 Fig. 7 is an illustrative representation of exemplary dimensions of
23 a receive antenna of the remote communication device.
24

1 Fig. 8 is an illustrative representation of an exemplary conductive
2 trace formed upon another substrate surface of the remote
3 communication device.

4 5 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

6 This disclosure of the invention is submitted in furtherance of the
7 constitutional purposes of the U.S. Patent Laws "to promote the
8 progress of science and useful arts" (Article 1, Section 8).

9 Fig. 1 illustrates a wireless communication system 10 embodying
10 the invention. Communication system 10 is configured as an electronic
11 identification system in the embodiment described herein. Other
12 applications of communication system 10 are possible. Further, the
13 described communication system 10 is configured for backscatter
14 communications as described further below. Other communication
15 protocols are utilized in other embodiments.

16 The depicted communication system 10 includes at least one
17 electronic wireless remote communication device 12 and an
18 interrogator 26. Radio frequency communications can occur intermediate
19 remote communication device 12 and interrogator 26 for use in
20 identification systems and product monitoring systems as exemplary
21 applications.

22 Devices 12 include radio frequency identification devices (RFID)
23 or remote intelligent communication (RIC) devices in the exemplary
24 embodiments described herein. Remote intelligent communication devices

1 can perform functions in addition to identification functions. Exemplary
2 devices 12 are disclosed in U.S. Patent Application Serial
3 No. 08/705,043, filed August 29, 1996. Plural wireless remote
4 communication devices 12 typically communicate with interrogator 26
5 although only one such device 12 is illustrated in Fig. 1. Such a
6 remote communication device 12 can be referred to as a tag or card
7 as illustrated and described below.

8 Although multiple remote communication devices 12 can be
9 employed in communication system 10, there is typically no
10 communication between multiple devices 12. Instead, the multiple
11 communication devices 12 communicate with interrogator 26. Multiple
12 communication devices 12 can be used in the same field of
13 interrogator 26 (i.e., within the communications range of
14 interrogator 26). Similarly, multiple interrogators 26 can be in proximity
15 to one or more of remote communication devices 12.

16 The above described system 10 is advantageous over prior art
17 devices that utilize magnetic field effect systems because, with system 10,
18 a greater range can be achieved, and more information can be
19 communicated (instead of just identification information). As a result,
20 such a system 10 can be used, for example, to monitor large warehouse
21 inventories having many unique products needing individual discrimination
22 to determine the presence of particular items within a large lot of
23 tagged products.
24

1 Remote communication device 12 is configured to interface with
2 interrogator 26 using a wireless medium in one embodiment. More
3 specifically, communications intermediate communication device 12 and
4 interrogator 26 occur via an electromagnetic link, such as an RF link
5 (e.g., at microwave frequencies) in the described embodiment.
6 Interrogator 26 is configured to output forward link wireless
7 communications 27. Further, interrogator 26 is operable to receive reply
8 or return link wireless communications 29 from remote communication
9 devices 12 responsive to the outputting of forward link
10 communication 27.

11 In accordance with the above, forward link communications 27 and
12 return link communications 29 individually comprise wireless signals, such
13 as radio frequency signals, in the described embodiment. Other forms
14 of electromagnetic communication, such as infrared, etc., are possible.

15 Interrogator unit 26 includes a plurality of antennas X1, R1, as
16 well as transmitting and receiving circuitry, similar to that implemented
17 in devices 12. Antenna X1 comprises a transmit antenna and
18 antenna R1 comprises a receive antenna individually connected to
19 interrogator 26.

20 In operation, interrogator 26 transmits the interrogation command
21 or forward link communication signal 27 via antenna X1.
22 Communication device 12 is operable to receive the incoming forward
23 link signal. Upon receiving signal 27, communication device 12 is
24

operable to respond by communicating the responsive reply or return link communication signal 29.

In one embodiment, responsive signal 29 is encoded with information that uniquely identifies, or labels the particular device 12 that is transmitting, so as to identify any object, animal, automobile, person, etc., with which remote communication device 12 is associated.

More specifically, remote communication device 12 is configured to output an identification signal within reply link communication 29 responsive to receiving forward link wireless communication 27. Interrogator 26 is configured to receive and recognize the identification signal within the return or reply link communication 29. The identification signal can be utilized to identify the particular transmitting communication device 12.

Referring to Fig. 2, one embodiment of remote communication device 12 is illustrated. The depicted remote communication device 12 includes communication circuitry 16 having a receiver and a transmitter. Communication circuitry 16 may be implemented as transponder circuitry in one configuration. Exemplary communication circuitry 16 includes a small outline integrated circuit (SOIC) 19 available as radio frequency identification device (RFID) circuitry from Micron Communications Inc., 3176 South Denver Way, Boise, Idaho 83705 under the trademark MicroStamp (TM) Engine and having designations MSEM256X10SG, MT59RC256R1FG-5.

1 Communication circuitry 16 is configured to receive and process
2 communication signals. Exemplary processing includes analyzing the
3 received communication signal for identification information and
4 processing commands within the communication signal. More or less
5 processing can be performed by communication circuitry 16. Thereafter,
6 communication circuitry 16 selectively generates communication signals for
7 communication to interrogator 26. Remote communication device 12
8 further includes a power source 18 connected to communication
9 circuitry 16 to supply operational power to communication circuitry 16
10 including integrated circuit 19.

11 Power source 18 is a thin film battery in the illustrated
12 embodiment, however, in alternative embodiments, other forms of power
13 sources can be employed. If the power source 18 is a battery, the
14 battery can take any suitable form. Preferably, the battery type will be
15 selected depending on weight, size, and life requirements for a particular
16 application. In one embodiment, battery 18 is a thin profile button-type
17 cell forming a small, thin energy cell more commonly utilized in watches
18 and small electronic devices requiring a thin profile. A conventional
19 button-type cell has a pair of electrodes, an anode formed by one face
20 and a cathode formed by an opposite face. In an alternative
21 embodiment, the battery comprises a series connected pair of button
22 type cells.

23 Communication device 12 further includes at least one antenna
24 connected to communication circuitry 16 and configured for at least one

1 of wireless transmission and reception. In the illustrated embodiment,
2 communication device 12 includes at least one receive antenna 44
3 connected to communication circuitry 16 for radio frequency reception
4 by communication circuitry 16, and at least one transmit antenna 46
5 connected to communication circuitry 16 for radio frequency transmission
6 by communication circuitry 16.

7 Receive antenna 44 is configured to receive forward wireless
8 signals 27 and apply communication signals corresponding to the received
9 wireless signals to communication circuitry 16. Transmit antenna 46 is
10 configured to receive generated communication signals from
11 communication circuitry 16 and output remote wireless signals 29
12 corresponding to the generated communication signals. The described
13 antennas are implemented as printed microstrip antennas in one
14 configuration. Further, receive antenna 44 comprises a loop antenna
15 and the transmit antenna 46 comprises a dipole antenna in the
16 described configuration. Transmit antenna 46 has plural dipole
17 halves 47, 48 in the configuration illustrated in Fig. 4.

18 Communication device 12 can be included in any appropriate
19 housing or packaging. Fig. 2 shows but one example of a housing in
20 the form of a miniature housing 11 encasing device 12 to define a tag
21 which can be supported by an object (e.g., hung from an object, affixed
22 to an object, etc.).

23 Referring to Fig. 3, an alternative configuration of remote
24 communication device 12a is illustrated. Fig. 3 shows remote

1 communication device 12a having a housing 11a in the form of a card.
2 Card housing 11a preferably comprises plastic or other suitable material.
3 Remote communication device 12a may be utilized as an employee
4 identification badge including the communication circuitry 16. In one
5 embodiment, the front face of housing 11a has visual identification
6 features such as an employee photograph or a fingerprint in addition
7 to identifying text.

8 Although two particular types of housings have been disclosed, the
9 communication device 12 can be included in any appropriate housing.
10 Communication device 12 is preferably of a small size that lends itself
11 to applications employing small housings, such as cards, miniature tags,
12 etc. Larger housings can also be employed. The communication
13 device 12, provided in any appropriate housing, can be supported from
14 or attached to an object in any desired manner.

15 Referring to Fig. 4, further details of one configuration of remote
16 communication device 12 are shown. The illustrated remote
17 communication device 12 includes a substrate 50 having plural surfaces
18 (surface 52 is shown in Fig. 4). The illustrated substrate 50 has
19 exemplary dimensions including a length l of 60 mm and a width w
20 of 53 mm.

21 In the described configuration of remote communication device 12,
22 substrate 50 comprises FR4 board. Conductive traces 53 are provided
23 upon surface 52 of substrate 50 to form desired circuitry including
24

1 interconnections, antennas, etc. Such traces 53 can be formed by
2 etching copper cladding provided upon surface 52.

3 As shown, conductive traces 53 include receive antenna 44 and
4 transmit antenna 46 individually formed upon surface 52. In addition,
5 traces 53 include power source connections for coupling with power
6 source 18 (shown in phantom in Fig. 3). More specifically, power
7 source connections include a positive voltage connection 54 and a
8 negative voltage connection 56 as shown.

9 A negative terminal of power source 18 may be electrically
10 coupled directly with negative connection 56. In the described
11 configuration, power source 18 is seated upon and coupled directly
12 above negative connection 56.

13 An elevated support connection 58 is formed elevationally above
14 power source 18 and substrate surface 52. Elevated support
15 connection 58 is coupled with a positive terminal of power source 18.
16 The positive terminal can be opposite the negative terminal of power
17 source 18 which is coupled with negative connector 56. Plural
18 conductive posts 60 are provided to couple elevated support
19 connection 58 with positive connection 54.

20 A via connection 62 is shown formed through substrate 50. Via
21 connection 62 provides coupling of negative connection 56 formed upon
22 surface 52 to an opposing surface of substrate 50 shown in Fig. 8. Via
23 connection 62 can provide coupling to a ground plane formed upon the
24 opposing surface as described below in further detail. Positive

1 connection 54 couples conductive posts 60 with receive antenna 44 and
2 a pin 3 (positive voltage input) of integrated circuit 19. Antenna 44
3 is additionally coupled with a pin 7 (RX input) of integrated circuit 19
4 as shown.

5 Conductive traces 53 formed upon surface 52 also couple
6 communication circuitry 16 and a capacitor 64 with other circuitry as
7 illustrated. Capacitor 64 is coupled with one lead of receive
8 antenna 44 and a via connection 66. Via connection 66 provides
9 electrical coupling of capacitor 64 with a ground connection upon the
10 opposing surface of substrate 50. Accordingly, capacitor 64 operates to
11 provide coupling of positive connection 54 with the ground reference
12 voltage of power source 18. Capacitor 64 is a 0.1 microfarad capacitor
13 in the described embodiment sufficient to provide static discharge
14 protection.

15 The formed conductive traces 53 also operate to couple the lead
16 of receive antenna 44 with pin 7 of integrated circuit 19. Pins 5, 6
17 of integrated circuit 19 are coupled with respective via
18 connections 68, 69. Via connections 68, 69 provide electrical connection
19 through substrate 50 to a transmission line described with reference to
20 Fig. 8. Via connections 71, 73 are coupled with opposite ends of the
21 transmission line and dipole halves 47, 48 of transmit antenna 46.
22 Integrated circuit 19 is electrically coupled with a plurality of pin
23 connections 67 of conductive traces 53. Plural pins 9, 13-16 of
24 integrated circuit 19 are coupled with a via connection 74 which is

1 coupled through the ground plane to the negative terminal of power
2 source 18.

3 In the illustrated configuration including power source 18 within
4 receive antenna 44, receive antenna 44 is tuned to a first frequency
5 (approximately 915 MHz in the described embodiment). Power
6 source 18 provides capacitive loading which assists with tuning of
- antenna 44 to the desired frequency.

8 Receive antenna 44 further includes an impedance reduction
9 strip 70 provided in a substantially rectangular configuration in the
10 depicted embodiment. Other configurations of impedance reduction
11 strip 70 are possible. Impedance reduction strip 70 comprises a
12 conductor which operates to effectively lower the impedance of receive
13 antenna 44 and provide enhanced operation of antenna 44 at another
14 higher frequency (e.g., 2.45 GHz) without excessive degradation of
15 communication at the first frequency (e.g., 915 MHz).

16 Thus, with impedance reduction strip 70, receive antenna 44 is
17 substantially tuned to a plurality of independent frequency bands
18 individually having a bandwidth of approximately twenty percent of the
19 highest center frequency (e.g., +/- 200 MHz for 2.45 GHz). Receive
20 antenna 44 is tuned to plural exclusive non-overlapping frequency bands
21 in the described arrangement. Receive antenna 44 is configured to
22 communicate wireless signals at a plurality of substantially resonant
23 frequencies. More specifically, the illustrated configuration of receive
24

1 antenna 44 can electromagnetically communicate with a return loss of
2 less than or equal to approximately -9 dB at the plural frequencies.

3 The illustrated configuration of transmit antenna 46 includes plural
4 vertical portions and horizontal portions. More specifically, dipole
5 half 47 includes a vertical portion 80 and a horizontal portion 82.
6 Dipole half 48 includes a vertical portion 84 and a horizontal
7 portion 86.

8 Additionally, transmit antenna 46 includes an impedance reduction
9 strip 72 formed in one exemplary configuration as illustrated in Fig. 4.
10 Impedance reduction strip 72 is a conductor formed adjacent one of the
11 leads of transmit antenna 46. Impedance reduction strip 72 operates
12 to reduce the impedance of dipole half 48 of transmit antenna 46 in
13 the depicted configuration. Other arrangements for impedance reduction
14 strip 72 are possible.

15 The illustrated transmit antenna 46 is configured to communicate
16 wireless signals at a plurality of substantially resonant frequencies.
17 Transmit antenna 46 is substantially tuned to a plurality of independent
18 frequency bands individually having a bandwidth of approximately twenty
19 percent of the highest center frequency. Transmit antenna 46 is tuned
20 to plural exclusive non-overlapping frequency bands in the described
21 arrangement.

22 For example, the depicted transmit antenna 46 is substantially
23 tuned to 915 MHz and 2.45 GHz. Horizontal portions 82, 86 of
24 transmit antenna 46 are tuned to substantially communicate at a first

1 frequency (e.g., 2.45 GHz communications). Vertical portions 80, 84 of
2 transmit antenna 46 in combination with horizontal portions 82, 86 are
3 tuned to provide communications at a second frequency (e.g., 915 MHz)
4 with horizontal portions 82, 86. Transmit antenna 46 is configured to
5 electromagnetically communicate with a return loss of less than or equal
6 to approximately -9 dB at the plurality of frequencies. Provision of
7 impedance reduction strip 72 operates to improve tuning of transmit
8 antenna 46 to the plural independent frequency bands.

9 Interrogator 26 (shown in Fig. 1) is configured to communicate
10 at one or more of a plurality of frequencies. The frequency of
11 communication intermediate interrogator 26 and remote communication
12 device 12 is generally controlled by interrogator 26. For example, in
13 some applications, a 915 MHz frequency may be desirable for longer
14 range communications while in other applications a 2.45 GHz frequency
15 may provide advantageous benefits (e.g., severe interference may be
16 experienced in another one of the frequency bands). Interrogator 26
17 outputs forward signals 27 at the desired frequency or frequencies.

18 Thereafter, interrogator 26 outputs a continuous wave signal at
19 one or more of the frequencies. Remote communication device 12
20 selectively modulates a received continuous wave signal during
21 backscatter communications. Accordingly, the modulated backscatter
22 return signal is provided at the original frequency of the continuous
23 wave signal outputted by interrogator 26. Thus, in the described
24 embodiment, the frequency of communication of remote communication

1 device 12 is determined responsive to a frequency of communication of
2 interrogator 26. Other communication methods may be utilized.

3 Referring to Figs. 5-7, exemplary dimensions of receive antenna 44
4 and transmit antenna 46 formed upon surface 52 are illustrated.
5 Referring specifically to Fig. 5, dipole half 47 of transmit antenna 46
6 is shown. Vertical portion 80 of dipole half 47 has a thickness a
7 of 2.3 mm. Vertical portion 80 additionally includes a length b
8 of 55 mm. Horizontal portion 82 has a length c of 22.3 mm.
9 Horizontal portion 82 additionally includes a width d of 3 mm.

10 Referring to Fig. 6, details of dipole half 48 are shown. Dipole
11 half 48 includes a vertical portion 84 and a horizontal portion 86
12 adjacent impedance reduction strip 72. Vertical portion 84 has an
13 equivalent width and length to that of vertical portion 80 of antenna
14 half 47. Further, horizontal portion 86 has a length equivalent to that
15 of horizontal portion 82 of antenna half 47. A dimension g including
16 the width of horizontal portion 86 and the width of impedance
17 reduction strip 72 is 7.73 mm. Another dimension h including a
18 reduced width of impedance reduction strip 72 and horizontal portion 86
19 is 5 mm. Further, a dimension i corresponding to one length of
20 impedance reduction strip 72 is 17 mm. The depicted dimensions
21 correspond to one configuration of transmit antenna 46 of remote
22 communication device 12. Other configurations are possible.

23 Referring to Fig. 7, exemplary dimensions of receive antenna 44
24 are shown. Receive antenna 44 includes horizontal portions 88-90. In

1 addition, receive antenna 44 includes vertical portions 92, 93.
2 Horizontal portions 88, 89 individually have a length corresponding to
3 a dimension m of 14.7 mm. Individual antenna portions 88-90, 92, 93
4 individually have a width corresponding to dimension n of 1.35 mm.
5 Vertical portions 92, 93 individually have a length o having a dimension
6 of 33.8 mm. Horizontal portion 90 also has a length of dimension o
7 of 33.8 mm. Impedance reduction strip 70 and horizontal portion 89
8 have a combined width p of 5.73 mm.

9 Referring to Fig. 8, a surface 55 of substrate 50 opposite
10 surface 52 described above is shown. Surface 55 of substrate 50
11 includes conductive traces 57 formed as shown in the described
12 embodiment. Conductive traces 57 can comprise etched copper cladding
13 in an FR4 board configuration.

14 The depicted conductive trace 57 includes a ground plane 96 and
15 a transmission line 97 comprising plural conductors 98, 99. Ground
16 plane 96 is coupled with negative connection 56 using via connection 62.
17 Further, ground plane 96 is also coupled with via connections 66, 74.

18 Transmission line 97 comprises a quarter-wavelength transmission
19 line in the described embodiment. Transmission line 97 operates to
20 couple backscatter pins 5, 6 of integrated circuit 19 shown in Fig. 4
21 with respective dipole halves 48, 47 of transmit antenna 46.
22 Transmission line 97 operates to provide an inverting function in
23 accordance with the described embodiment. For example, if integrated
24 circuit 19 short circuits pins coupled with via connections 68, 69, an

1 open circuit is seen at via connections 71, 73 coupled with antenna
2 halves 47, 48. Conversely, if an open circuit is provided intermediate
3 via connections 68, 69, a short circuit is seen at via connections 71, 73
4 for 2.45 GHz communications.

5 Various dimensions of conductive trace 57 are provided below in
6 accordance with an exemplary configuration. Other configurations are
7 possible. In the described embodiment, ground plane 96 includes a
8 width of dimension s of 8.44 mm. Further, ground plane 96 has a
9 length t of 34 mm. Conductors 98, 99 individually have a length
10 corresponding to dimension u of 10.5 mm. Further, individual
11 conductors 98, 99 have a width of 1 mm.

12 Provision of a remote communication device 12 as described
13 herein provides improved communications at plural independent frequency
14 bands. For example, such a remote communication device 12 has been
15 observed to have a forward range of approximately 170 feet and a
16 return range of approximately 300 feet at 915 MHz. Further, the
17 remote communication device has been observed to have a forward
18 range of 28 feet and a return range of 90 feet at 2.45 GHz.

19 In compliance with the statute, the invention has been described
20 in language more or less specific as to structural and methodical
21 features. It is to be understood, however, that the invention is not
22 limited to the specific features shown and described, since the means
23 herein disclosed comprise preferred forms of putting the invention into
24 effect. The invention is, therefore, claimed in any of its forms or

1 modifications within the proper scope of the appended claims
2 appropriately interpreted in accordance with the doctrine of equivalents.
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